Quarterly Status Report
(January 12, 1966)

Contract R-80

between

The National Bureau of Standards

and

The National Aeronautics and Space Administration

October 1, 1965 through December 31, 1965

1. Thick-target bremsstrahlung. The computer program developed for this problem has assumed its final form, and has been generalized into a full-fledged cascade calculation; i.e., it follows not only the bremsstrahlung produced by the incident primary electrons, but also that produced by secondary electrons which have themselves been set in motion by bremsstrahlung photons.

Systematic calculations have been made for electrons with energies between 50 kev and 10 Mev incident on aluminum tungsten and gold targets. The results include the so-called bremsstrahlung efficiencies (fraction of the incident electron energy that emerges from the target in the forward and backward directions), as well as more detailed information on the angular and spectral distribution of the emergent bremsstrahlung. As a by-product, information was also obtained about electron transmission and reflection by the target.

The calculations were done with the use of bremsstrahlung production cross section based on the Bethe-Heitler theory modified according to the experimental information compiled by Koch and Motz. These empirical corrections raise the cross sections by up to 30% for aluminum, and up to 80% for tungsten, the corrections being greatest at energies around 0.5-1.0 Mev.

Comparisons with measurements made by Dance and Baggerly at LTV indicates reasonably good agreement as to the shapes of the angular and spectral distribution but a systematic discrepancy as to the absolute normalization. The discrepancy is particularly noticeable for incident 0.5-Mev electrons, in which case, at practically all angles and spectral energies, the experimental results lie about 35-40% below the calculated results. It thus appears that the LTV data indicate that one would get better agreement by taking Bethe-Heitler theory straight, without empirical modifications. This is also suggested by preliminary bremsstrahlung measurements by the same group at LTV which indicate that the cross sections are, if anything, lower than the predictions of Bethe-Heitler theory.

The computer program can of course accept any desired bremsstrahlung cross sections. At present computations are in progress based on straight Bethe-Heitler cross sections. It is anticipated that additional runs will be made in the future, as more experimental and theoretical information becomes available on bremsstrahlung cross sections.

The program has also been put in operation at the Houston Manned Spacecraft Center, to supply required shielding information.

Liaison is being maintained with experimental groups at NRDL and at General Atomic who are also engaged in the measurement of thick-target bremsstrahlung.

2. Electron Transmission. The computer program developed at NBS has been used in systematic calculations at the Manned Spacecraft Center in Houston, pertaining to electrons with energies up to 8 Mev from isotropic and cosine-law sources incident on aluminum targets.

Detailed calculations have been made of the angular and spectral distribution of 1-Mev electrons incident on aluminum targets, for comparison with measurements by Rester at LTV. The agreement is on the whole good. However, the widths of the experimentally observed transmitted energy spectra are generally somewhat greater than the calculated widths.

Very preliminary comparisons have also been made with transmission measurements by Jupiter and collaborators at General Atomic for 8-Mev

electrons incident on aluminum. Again, the measured spectra have a greater width than the calculated spectra.

Good agreement has been found between calculations and experimental results obtained by Singh at Langley Research Center for 1.0, 1.5 and 2.0 Mev electrons transmitted through silicon, the comparison being made through the scaling of calculated 1-Mev aluminum data. Specific calculations for silicon are planned.

The width of the transmission energy spectra is related to the energy-loss straggling theory that is entered into the electron Monte Carlo program. In the existing program, use is made of the theory of Landau as modified by Blunck and Leisegang. The question is now being examined whether, within the framework of the Monte Carlo model, this is the best possible procedure. Various alternatives are under consideration including use of a theory by Williams which is a predecessor of the Landau theory and would lend itself particularly well to the exact treatment of energetic secondary knock-on electrons.

3. Energy dissipation within target. As a by-product of the thick-target bremsstrahlung work, data have also obtained on the depth dose within plane-parallel targets of aluminum and tungsten, for perpendicular as well as oblique incidence. This information may be of interest in connection with radiation damage considerations.

4. Energy dissipation by electrons in the earth's atmosphere. At the suggestion of Dr. Hess of the Goddard Space Flight Center, a calculation is being undertaken of the energy dissipation by electrons injected into the atmosphere from the top (at 300 km), as function of height in the atmosphere and of the radial distance from the point of injection. This information is sought because of its bearing on the explanation of auroral phenomena. From the standpoint of transport theory, the novel aspects are two: the influence of the density variation of the atmosphere, and of the magnetic field, on the motion of the electrons. A computer program has been written adn has now reached the de-bugging stage.

Planned Activities during 1966:

1. The large body of data on thick-target bremsstrahlung that has been generated will be organized and made available for general use. Through liaison with scientists at various laboratories such as LTV, NRDL and General Atomic, a continuing check will be made on the agreement between calculation and experiment. If new and improved bremsstrahlung cross sections should become available, new thick-target runs will be made.

2. The work on energy dissipation by electrons in the atmosphere will be completed for the case of a uniform magnetic field in the vertical direction (conditions approximated in polar regions). There is the possibility of an extension of this work to more general magnetic fields.

3. The work on electron transmission will have its immediate aim the re-investigation of the phenomena of energy loss straggling and production of secondary knock-on electrons. An attempt will also be made to arrange the computations so that the transmission spectra can be obtained for specific angles of emergence, rather than in histogram form. This should facilitate comparison with experiments, and would also allow the inclusion of the dependence on the azimuth between the directions of incidence and emergence.

4. Some effort will go into calculations of electron transport in inhomogeneous media, with emphasis on energy dissipation in the vicinity of a plane interface.